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An Overview of Studies on the Impact of Nickel on Selected Fabaceous Plants and Their Role in Phytoremediation

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Abstract: Nickel (Ni) accumulation in Fabaceous plants significantly impacts plant physiology, growth, and biochemical processes. At elevated concentrations, nickel induces oxidative stress, disrupts photosynthetic mechanisms, and alters membrane permeability. Plants exhibit reduced biomass, chlorophyll content, and photosynthetic efficiency. Furthermore, Ni's interference in the photosynthetic machinery (i.e., inhibition of chlorophyll biosynthesis and disruption of electron transport) can significantly decrease photosynthesis, cause leaf chlorosis and reduce overall plant biomass. In addition, all growth parameters such as root elongation and shoot development will be negatively impacted by Ni stress, especially with respect to competition for uptake with other essential nutrients. Physiological responses include decreased root and shoot growth, impaired nutrient uptake and increased production of reactive oxygen species (ROS). However, some Fabaceae species exhibit metal-tolerance mechanisms such as root exclusion, cellular compartmentalization and metal chelation. The phytoremediation potential varies among species, with some plants capable of accumulating substantial amounts of nickel, making them potential candidates for environmental remediation of nickel-contaminated sites.

Introduction

Fabaceous plants, commonly known as legumes, are a diverse group of economically important crops that play a crucial role in global food production and sustainability. Legumes, such as soybeans, peas, lentils, and alfalfa, are valued for their ability to fix atmospheric nitrogen through symbiotic relationships with nitrogen-fixing bacteria. This unique capacity enhances soil fertility and reduces the need for synthetic nitrogen fertilizers, making legumes an integral component of sustainable agricultural systems (Samreen et al., 2021). In addition to their importance as food and feed crops, fabaceous plants have garnered attention for their potential in phytoremediation, the use of plants to remove, transfer, stabilize, or degrade environmental contaminants (Jali et al., 2019). Certain legume species have demonstrated the ability to accumulate and tolerate high levels of heavy metals, including nickel (Ni), in their tissues. Nickel is a naturally occurring trace element that is essential for plant growth and development, but it can become toxic at elevated concentrations, especially in agricultural soils impacted by industrial activities, mining, or the application of nickel-rich fertilizers and sewage sludge (Shi et al., 2023). The response of Fabaceae to nickel stress is therefore an important area of research, as it has implications for crop productivity, food safety, and environmental remediation (Hassan et al., 2019; Pandey, 2020). The response of fabaceous plants to nickel stress is, therefore, an important area of research, as it has implications for crop productivity, food safety and

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environmental remediation. Understanding the mechanisms by which legumes respond to and tolerate nickel toxicity can inform strategies for developing nickel-resistant cultivars or optimizing phytoremediation approaches (Das et al., 2019; Mendes et al., 2023).

This review article aims to synthesize the current understanding of the effects of nickel on fabaceous plants, encompassing aspects of nickel uptake and translocation, physiological and biochemical responses, morphological and anatomical changes, and the strategies employed by legumes to tolerate nickel toxicity (Pasricha et al., 2021; Feng et al., 2021). Phytoextraction is an innovative and cost-effective technology that utilizes plants to remove metals from contaminated soils. This process involves the uptake of metals by plant roots, which then translocate them to harvestable shoots (Manirakiza et al., 2018). The contaminated plant biomass is subsequently harvested, thereby removing the metals from the soil (Awa & Hadibarata, 2020). Additionally, the review will explore the potential of Fabaceae for phytoremediation of nickel-contaminated soils. By compiling and analyzing the existing literature, this review will provide a comprehensive overview of the topic and identify knowledge gaps that warrant further investigation.

Pollution is a global topic of discussion as it leads to global warming and climate change. The major cause of environmental pollution is the addition of different pollutants from several sources (Singh & Yadav, 2021; Fuller et al., 2022). The sources are mainly high industrialization, mining, urbanization, the use of fertilizer, and many more. The contaminated soil, air, and water cause several human, animal, and plant diseases (Dijoux et al., 2020). Heavy metal pollution is the most common pollution as it has very adverse effects on agriculture and human health care (Vardhan et al., 2019; Williams, 2019). There are more than 25 heavy metals are there which are more common types of pollutants nowadays. Nickel is one of them and is mostly found in the soil of Odisha (Sahoo et al., 2018). It is the state of high mining and the rapid mining results in atmospheric pollution. The percentage of total Indian Ni is controlled by Odisha as it has a total of 93% of the contribution. According to a report from the India Bureau of Mines, Nickel metal is found in the Sukinda Valley of Odisha in a lateritic form. As Ni has a high economic value, the ore mining becomes more and more profitable (Mishra et al., 2018). It results in the deposition of metal in the soil, which increases. The use of different fertilizers is also a cause of metal addition. in the soil. The agricultural biomass also takes part in the heavy metal addition (Chen et al., 2024). Due to the high pollution in this century, the agricultural field is most affected. Heavy metals can disrupt soil microbial communities, reduce soil fertility and harm plant and animal life. They can also contaminate water bodies through leaching and runoff, further spreading their toxic effects (Laoye et al., 2025). The wild variety is now mutated due to changes in the condition and physiology. The effects of toxic metals lead to deleterious changes in the product's nutrient and food value. Ni has a very toxic effect on plants after a certain tolerance limit as it slows down photosynthesis transpiration and other metabolic and biochemical functions. For plant growth and development several metals are essential for various developmental processes (Riyazuddin et al., 2021). Among them, Ni plays an important role in nitrogen metabolism. It is one of the essential micronutrients of the plant as it is involved in Urease activity.

Importance of fabaceous plants (legumes)

Legumes, or fabaceous plants, are a diverse family of crops that include soybeans, peas, lentils, beans, and peanuts, crucial for food production and sustainable farming (Siddiqui et al., 2025). They enhance soil health by fixing nitrogen through a symbiosis with bacteria, reducing the need for fertilizers. Rich in protein, fiber and essential nutrients, legumes support food security and nutrition, especially in plant-based diets (Khan et al., 2024). Their role in crop rotation also improves soil structure, reduces erosion, and helps control pests, making them essential for sustainable agriculture and resilient food systems.

One of the key features that makes legumes so valuable is their ability to fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing bacteria, primarily Rhizobium species. These bacteria reside in specialized root nodules and convert atmospheric nitrogen (N_2) into ammonia (NH_3), which the plant can then assimilate and utilize for growth and development. This unique nitrogen-fixing capacity of legumes helps to enrich the soil with nitrogen, reducing the need for synthetic nitrogen fertilizers (Tak & Gehlot, 2019; Raza et al., 2020; Siddiqui et al., 2025).

In addition to their role in improving soil fertility, legumes are an essential source of dietary protein, fiber, complex carbohydrates, and a variety of vitamins and minerals. Legumes are particularly important in regions where access to animal-based protein sources is limited, as they can serve as a cost-effective and sustainable alternative (Vasconcelos et al., 2020). Furthermore, the high protein and fiber content of legumes makes them

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valuable for human and animal nutrition, contributing to food security and healthy diets (Reinprecht et al., 2020).

Legumes also play a crucial role in crop rotation and intercropping practices, which are important components of sustainable agriculture. The nitrogen-fixing ability of legumes can enhance the growth and yield of subsequent non-leguminous crops, reducing the need for synthetic fertilizers and improving overall farm productivity (Pierre & J.E., 2024).

Given their multifaceted contributions to food production, soil fertility, and sustainable agricultural systems, the study of fabaceous plants and their responses to environmental stressors, such as heavy metal contamination, is of great importance.

Role of nickel in plant growth and development

Nickel (Ni) is a vital trace element for plants, contributing to essential physiological and biochemical functions. It plays a key role in enzyme activation, particularly in urease, which helps convert urea into usable nitrogen forms (Kováčik et al., 2024). Nickel also supports nitrogen metabolism, seed germination, and disease resistance. Although required in only small amounts, a deficiency in nickel can impair plant growth, reduce seed viability, and affect nutrient absorption, making it crucial for healthy plant development. One of the primary functions of nickel is its involvement in the urea cycle (Liu et al., 2022; Shahzad et al., 2023). Nickel is a cofactor for the enzyme urease, which catalyzes the hydrolysis of urea into carbon dioxide and ammonia. This process is important for the efficient utilization of nitrogen by plants, as it allows them to recycle and assimilate nitrogen from urea, a common by-product of nitrogen metabolism (Ma et al., 2025).

In addition, nickel is necessary for the activation of several other enzymes, including glyoxalase I, methylglyoxalase, and superoxide dismutase. These enzymes are involved in the detoxification of reactive oxygen species, the regulation of osmotic potential, and the maintenance of cellular redox balance, all of which are essential for proper plant growth and stress responses (Panda et al., 2022).

Furthermore, nickel has been shown to play a role in the production of secondary metabolites, the regulation of plant hormone levels, and the development of reproductive structures, such as flowers and seeds. It also contributes to the structural integrity of plant cell walls and membranes.

However, while nickel is an essential micronutrient, it can become toxic to plants at elevated concentrations. Excessive nickel can disrupt various physiological and biochemical processes, leading to growth inhibition, nutrient imbalances, oxidative stress, and even plant death (Mitra et al., 2020). Understanding the delicate balance between nickel's beneficial and detrimental effects on plants is crucial for developing strategies to mitigate nickel toxicity and promote sustainable plant growth.

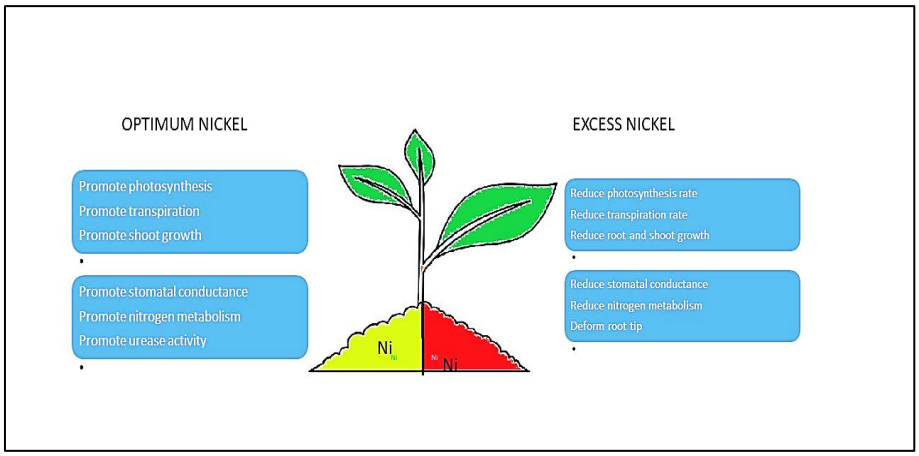

Figure 1. Effect of nickel on plants at optimum and excess concentrations.

Rationale for reviewing the effects of nickel on Fabaceous plants

Fabaceous plants are widely cultivated for their protein-rich seeds and ability to fix atmospheric nitrogen, making them crucial contributors to global food production and sustainability. Understanding the impacts of nickel on these crops is essential for maintaining agricultural yields and soil fertility. Certain Fabaceous species have demonstrated the ability to accumulate and tolerate high levels of nickel in their tissues, making them potential candidates for phytoremediation of nickel-contaminated soils (Sujkowska-Rybkowska et al., 2022; Mussali-Galante et al., 2023). A detailed review of the literature could identify the most promising Fabaceous species and mechanisms for nickel uptake and tolerance.

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Excess nickel in the environment can harm plant and animal life. A comprehensive understanding of the effects of nickel on Fabaceous plants can inform environmental risk assessments and the development of strategies for mitigating nickel contamination (Pandey, 2020).

A literature review can synthesize the current state of knowledge, help identify gaps in our understanding of nickel-Fabaceous plant interactions, and suggest promising avenues for future research. This can guide the design of more targeted and impactful studies in this field.

Nickel Uptake and Translocation in Fabaceous Plants

Nickel (Ni) is an essential micronutrient for plant growth and development, playing a crucial role in various physiological processes. However, excess Ni can be toxic to plants, leading to stunted growth, chlorosis, and other detrimental effects. Understanding the mechanisms of Ni uptake and translocation in plants is essential for developing strategies to mitigate Ni toxicity and optimize Ni utilization (Khudhur & Albarzinji, 2023).

Nickel uptake in Fabaceous plants involves several key steps:

1. **Root Ni Absorption**: Ni is primarily absorbed by plant roots through various membrane transporters, including the IRT1 (Iron-Regulated Transporter 1) and HMA (Heavy Metal ATPase) families. These transporters facilitate the influx of Ni into root cells (Deng et al., 2018).
2. **Chelation and Compartmentalization**: Once inside the root cells, Ni is often chelated by organic acids, amino acids, or other ligands to prevent toxicity. These Ni-chelates are then compartmentalized in the vacuole or other organelles, reducing the concentration of free Ni in the cytoplasm (Kumar et al., 2025).
3. **Root-to-Shoot Translocation**: Nickel is transported from the roots to the shoots through the xylem, the plant's water-conducting tissue. This process is mediated by specific Ni transporters, such as members of the NRAMP (Natural Resistance-Associated Macrophage Protein) family (Nishida et al., 2020; Li et al., 2022).

Several factors can influence the uptake and translocation of Ni in Fabaceous plants:

1. **Soil Ni Availability**: The concentration of Ni in the soil, as well as its chemical speciation, directly affects the amount of Ni available for plant uptake.
2. **Plant Species and Cultivars**: Different Fabaceous plant species and even cultivars within the same species can exhibit varying Ni uptake and translocation capacities, depending on their genetic makeup and underlying physiological mechanisms.
3. **Environmental Conditions**: Factors such as soil pH, temperature, moisture, and the presence of other minerals can affect Ni solubility and availability, thereby influencing its uptake and translocation within the plant (Mahmud et al., 2020).
4. **Symbiotic Interactions**: Fabaceous plants often form symbiotic relationships with nitrogen-fixing bacteria, such as rhizobia. These interactions can influence Ni uptake and partitioning within the plant (Shafiq et al., 2024).

Nickel availability in soils

Nickel (Ni) occurs naturally in soils, with concentrations typically ranging from 0.2 to 450 mg/kg, depending on the soil type and geological origin. The availability of Ni in soils is influenced by several key factors:

1. Soil pH: Nickel availability generally increases as soil pH decreases (becomes more acidic). In acidic soils, Ni is more soluble and accessible for plant uptake.
2. Organic matter content: Soil organic matter can bind to Ni, reducing its availability. However, as organic matter decomposes, it can also release Ni back into the soil solution (El-Naggar et al., 2021).
3. Redox conditions: Under anaerobic (low oxygen) conditions, Ni can form insoluble sulfide minerals, reducing its availability. Conversely, in aerobic soils, Ni is more soluble and mobile.
4. Clay content and cation exchange capacity (CEC): Soils with higher clay content and CEC tend to have greater Ni-holding capacity, which can limit Ni availability.
5. Presence of other metals: The availability of Ni can be affected by the presence and concentrations of other heavy metals in the soil, as they can compete for binding sites and uptake.

Understanding these factors is crucial when evaluating the potential of Ni phytoremediation using Fabaceae (legume) plants, as the bioavailability of Ni in the soil will directly affect plant uptake and accumulation.

Sources of Nickel Pollution in India

- Industrial activities: Nickel is used in various industries like electroplating, stainless steel production, mining, and battery manufacturing. Improper waste disposal from these industries can lead to soil contamination.
- Agricultural inputs: Some fertilizers, pesticides, and sewage sludge can contain elevated levels of nickel, contributing to soil pollution (Begum et al., 2022).

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- Vehicular emissions: Nickel is also released into the environment from the combustion of fossil fuels in vehicles.

highest levels observed near active and abandoned mine sites.

- Hotspots of nickel pollution have been identified

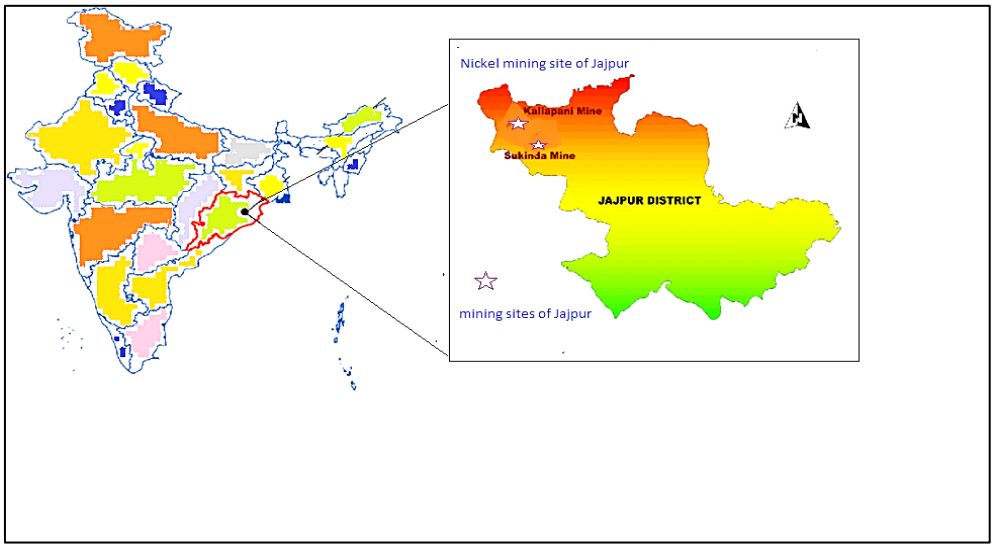

Figure 2. Map of Nickel mining sites of Odisha, India.

Nickel Contamination Levels in Indian Soils:

- Studies have reported elevated nickel concentrations in soils around industrial hubs, mining areas, and agricultural lands receiving wastewater irrigation.
- Nickel levels in Indian soils have been found to range from 0.2 to 2,300 mg/kg, with some hotspots exceeding the safe limit of 75 mg/kg set by the Indian government (Selvam et al., 2024).
- Regions with significant nickel pollution include industrial areas in states like Odisha, Maharashtra, Gujarat, Tamil Nadu, and Jharkhand.

Nickel pollution in Odisha

Odisha, a state located on the eastern coast of India, has been facing significant issues with nickel pollution in its soils (Fig. 2). Here's a more detailed overview of the nickel pollution problem in Odisha:

Sources of Nickel Pollution in Odisha:

Mining and mineral processing activities: Odisha is a major mining hub, with extensive deposits of nickel-bearing ores. Improper management of mining waste and ore processing has led to elevated nickel levels in the surrounding soils.

Industrial activities: The state has a strong industrial base, including stainless steel production, electroplating, and battery manufacturing units, which have contributed to nickel contamination. Agricultural practices: The use of nickel-containing fertilizers, pesticides and irrigation with contaminated water has also exacerbated the problem in agricultural lands.

Nickel contamination in Odisha.

- Studies have reported nickel concentrations in Odisha soils ranging from 20 to 1,500 mg/kg, with the highest levels observed in the districts of Jajpur, Keonjhar, Sundargarh and Angul, which are major mining and industrial hubs in the state (Deep et al., 2023).
- The nickel levels in some areas exceed the safe limit of 75 mg/kg set by the Indian government, posing a significant risk to the environment and human health.

Mechanisms of nickel uptake by plant roots

Nickel (Ni) is an essential micronutrient for plants, involved in processes such as urease activity and seed germination. Plants take up nickel from the soil through roots, primarily in the form of divalent nickel ions (Ni^{2+}) (Mustafa et al., 2023). The mechanism of nickel uptake by plant roots generally involves several steps (Fig. 3):

1. **Passive uptake:** Nickel can enter plant roots via passive diffusion down concentration gradients.
2. **Carrier-mediated transport:** Specialized nickel transporter proteins in root cell membranes actively shuttle nickel ions into the plant. This requires energy.
3. **Chelation and complexation:** Plant roots can secrete organic compounds that bind to nickel, facilitating its absorption and transport within the plant.
4. **Root exudates:** Roots release various compounds into the soil, some of which can solubilize and mobilize nickel, making it more available for uptake (Hassan et al., 2019).
5. **Root morphology:** The surface area, branching and other physical characteristics of plant roots impact their ability to absorb nickel from the soil.

Translocation of nickel from roots to shoots

The movement of nickel from the roots to the aerial portions of the plant occurs via the transpiration stream - the upward flow of water and dissolved minerals driven

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by evaporation from the leaf surfaces. Nickel primarily exists as the free Ni^{2+} ion within the xylem sap, but it can also form complexes with organic compounds like amino acids and organic acids, which can influence its mobility (Ge et al., 2020).

The extent of nickel translocation varies considerably between plant species and cultivars. Some hyperaccumulator plants have evolved the remarkable ability to translocate and store exceptionally high concentrations of nickel, up to 1-3% of their dry shoot biomass. This efficient root-to-shoot transport allows these plants to thrive in nickel-rich environments. Factors that can impact the degree of nickel translocation include the plant's root characteristics, the availability of nickel in the surrounding soil, environmental conditions like pH and temperature, and the plant's overall nutritional status and growth stage (Ge et al., 2020). Generally, higher soil nickel levels lead to greater nickel accumulation in the aboveground tissues, as more of the metal is available for root uptake and subsequent translocation.

The efficient translocation of nickel from roots to shoots is a critical process that allows plants to distribute and utilize this essential micronutrient throughout their structures. Understanding the mechanisms and influencing factors of this transport pathway is key to understanding nickel's role in plant nutrition and growth.

Physiological and Biochemical Responses of Fabaceous Plants to Nickel

As a mechanism to mitigate the oxidative stress imposed by nickel, fabaceous plants mount a specialized antioxidant defense system. This involves the upregulation of enzymes like superoxide dismutase and catalase, which work to neutralize the reactive oxygen species generated in response to nickel exposure (Santoyo-Martínez et al., 2024).

Certain legume species and cultivars have evolved sophisticated strategies to tolerate and sequester high levels of nickel. These plants can compartmentalize and store the absorbed nickel within cell walls, vacuoles, and specialized nickel-containing proteins, preventing the metal from disrupting critical cellular functions (Mendes et al., 2023). This allows some fabaceous hyperaccumulators to amass exceptionally high concentrations of nickel in their tissues.

Overall, the physiological and biochemical responses of legumes to nickel exposure demonstrate the plants' remarkable capacity to adapt to this heavy metal stress through a combination of uptake regulation, metabolic adjustments, antioxidant activation and specialized nickel tolerance mechanisms (Farago et al., 2024).

Effects on seed germination and seedling growth

Nickel (Ni) exerts profound detrimental effects on plant growth across multiple physiological dimensions. When accumulating in plant tissues, nickel disrupts fundamental metabolic processes by generating reactive oxygen species that damage cellular membranes, proteins and DNA structures. This oxidative stress leads to significant reductions in plant biomass, with observable decreases in root and shoot elongation, leaf area and overall plant development. Photosynthetic efficiency declines markedly as nickel interferes with chlorophyll synthesis and disrupts electron transport in chloroplasts (Kumar & Verma, 2018). Importantly, nickel toxicity impairs nutrient uptake, particularly of iron and calcium, further compromising plant growth and metabolism. Root systems undergo substantial morphological alterations, including reduced root hair development and decreased root elongation rates, ultimately limiting water and nutrient acquisition. Some fabaceous plants exhibit differential tolerance through metal chelation mechanisms and antioxidant enzyme production, but prolonged nickel exposure consistently results in growth inhibition, reduced photosynthetic capacity and potential plant mortality (Deswal & Laura, 2018).

Nickel significantly impairs seedling growth through multiple physiological mechanisms. During early developmental stages, nickel induces oxidative stress, disrupting root and shoot elongation and resulting in stunted seedling growth (Thakur & Sharma, 2016). The metal interferes with seed germination rates, reducing emergence percentage and initial vigor. At cellular levels, nickel accumulation damages meristematic tissues, inhibits cell division and impedes root hair development (Vyas, 2022). Photosynthetic processes are substantially compromised, with decreased chlorophyll synthesis and photosynthetic efficiency. Seedlings exhibit reduced biomass, shorter internodal distances, and diminished leaf expansion. Nutrient absorption mechanisms are disrupted, leading to mineral imbalances and impaired metabolic functions. Antioxidant enzyme systems become overwhelmed, causing membrane lipid peroxidation and cellular damage. Consequently, seedling survival and establishment are critically challenged, with growth rates directly proportional to nickel concentration in the growth medium.

Impacts on photosynthesis and chlorophyll content

Nickel profoundly disrupts photosynthetic processes and chlorophyll content in plants. The heavy metal significantly reduces total chlorophyll concentration through multiple mechanisms (Qin et al., 2022). Nickel interferes with chlorophyll biosynthesis by inhibiting key

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enzymatic reactions in the chloroplast, leading to decreased chlorophyll a and b production. Oxidative stress induced by nickel causes degradation of chlorophyll molecules and impairs the functionality of the photosynthetic apparatus.

At cellular levels, nickel accumulation damages thylakoid membranes, compromises photosynthetic pigment integrity and generates reactive oxygen species that further degrade chloroplast structures (Nabi et al., 2020). Photosynthetic efficiency declines dramatically, with studies demonstrating up to 50-70% reduction in total chlorophyll content at moderate to high nickel concentrations. The metal's interference with magnesium incorporation and chlorophyll protein complexes directly contributes to photosynthetic productivity losses, ultimately limiting plant carbon assimilation and overall metabolic performance (Liu et al., 2024).

Changes in antioxidant defense systems

Nickel (Ni) significantly influences antioxidant defense systems by disrupting the delicate oxidative balance in organisms. When organisms are exposed to nickel, it primarily triggers oxidative stress through enhanced production of reactive oxygen species (ROS) (Shahzad et al., 2018; Pishchik et al., 2021). This metal directly interferes with cellular antioxidant defenses by depleting glutathione (GSH), a crucial antioxidant molecule. Additionally, nickel exposure typically suppresses the activities of major antioxidant enzymes, including superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx), which normally protect cells from oxidative damage (Abbas et al., 2025).

Interestingly, nickel can stimulate a protective response at low concentrations, where organisms increase their antioxidant enzyme production as an adaptive mechanism. However, this response is highly dependent on both nickel concentration and exposure duration. Higher concentrations and prolonged exposure periods generally result in more severe impairment of antioxidant defense systems.

These alterations in antioxidant mechanisms can lead to cellular damage, potentially affecting various biological functions. The specific effects may vary depending on the organism type and exposure conditions, highlighting the complexity of nickel's interaction with biological systems.

Morphological and Anatomical Changes in Fabaceous Plants under Nickel Stress

Nickel stress induces substantial morphological and anatomical modifications in Fabaceous (legume) plants, significantly impacting their growth, development and overall survival. At the morphological level, the most noticeable changes include a marked reduction in root and shoot growth, accompanied by distinctive leaf chlorosis (yellowing) due to disrupted chlorophyll synthesis. Plants typically exhibit stunted growth with decreased leaf size and number, while their overall biomass production diminishes considerably. The root system shows particular sensitivity, with reduced nodulation affecting the plant's nitrogen-fixing capability, which is crucial for legumes. Visible symptoms often include wilting and leaf curling, indicating disrupted water relations within the plant tissues.

The anatomical alterations under nickel stress are equally significant and occur at various cellular and tissue levels. Leaf anatomy undergoes considerable modification, characterized by reduced mesophyll tissue thickness and altered chloroplast structure, which directly impacts photosynthetic efficiency (Adejumo et al., 2021). The cell walls often show increased thickness, possibly as a defensive mechanism against metal stress, while the organization of the root cortex becomes disrupted, affecting nutrient and water uptake. The vascular tissues, essential for water and nutrient transport, exhibit reduced development, potentially limiting the plant's ability to distribute resources. Stomatal modifications, including changes in size and density, affect gas exchange and water regulation. Perhaps most critically for legumes, the nodule structure and development are compromised, affecting their symbiotic relationship with nitrogen-fixing bacteria.

The severity of these morphological and anatomical changes typically correlates with nickel concentration and exposure duration. However, different Fabaceous species exhibit varying levels of tolerance, with some developing adaptive mechanisms to cope with nickel stress. Environmental conditions and the plant's growth stage also play crucial roles in determining the extent of these modifications. Understanding these changes is essential for developing strategies to improve legume crop resistance to nickel contamination and for phytoremediation applications (Abbas et al., 2025; Adejumo et al., 2021).

Nickel Toxicity Tolerance Mechanisms in Fabaceous Plants

Nickel (Ni) is a heavy metal that can be toxic to plants at high concentrations, but some Fabaceous plants have developed remarkable mechanisms to tolerate and even hyperaccumulate nickel. At the cellular level, Fabaceous plants deploy a multi-layered defense system against nickel-induced stress. The primary line of defense

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involves robust antioxidant systems. When nickel ions penetrate plant tissues, they trigger the production of reactive oxygen species (ROS), which can cause significant cellular damage. In response, plants dramatically upregulate antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (Abbas et al., 2025; Pishchik et al., 2021). These enzymes work synergistically to neutralize ROS, preventing oxidative stress and maintaining cellular integrity.

Phytochelatin production emerges as another critical defense mechanism. These small, cysteine-rich peptides act as molecular sponges, actively chelating nickel ions and reducing their free concentration within plant cells. By binding to nickel, phytochelatins effectively neutralize the metal's potential toxic interactions with cellular components, providing a crucial protective strategy.

Fabaceous plants demonstrate remarkable adaptability in protecting cellular membranes from nickel-induced damage. They modify membrane lipid compositions by altering fatty acid saturation and by incorporating additional antioxidant lipids. This strategic restructuring helps maintain membrane fluidity and prevents lipid peroxidation, ensuring continued cellular functionality under metal stress (Manjunatha et al., 2019).

At the molecular level, Fabaceous plants activate a complex network of stress-response genes. Metallothionein proteins (Mussali-Galante et al., 2024), characterized by their low molecular weight and high cysteine content, play a crucial role in metal ion neutralization. These proteins bind metal ions, providing an additional layer of cellular protection (Jach et al., 2022).

Genetic expression shifts dramatically under nickel stress, with plants upregulating specific genes responsible for metal transport, chelation, and stress response. This genetic plasticity allows for rapid adaptation to changing environmental conditions, demonstrating the sophisticated evolutionary strategies of Fabaceous plants.

Phytoremediation Potential of Fabaceous Plants for Nickel-Contaminated Soils

Phytoremediation, an eco-friendly and cost-effective technique, employs plants to detoxify contaminated environments, including those polluted with heavy metals such as nickel (Ni). Among plant families, the Fabaceae (legumes) show immense potential for remediation of nickel-contaminated soil due to their unique physiological traits and adaptability to harsh conditions (Moameri et al., 2017). Fabaceous plants are known for their symbiotic association with nitrogen-fixing bacteria (rhizobia), which enables them to enrich soil fertility even in nutrient-depleted and metal-polluted areas. This dual function of improving soil health while remediating heavy metals makes legumes particularly valuable in phytoremediation (Antonkiewicz et al., 2017). These plants utilize mechanisms such as rhizofiltration, phytoaccumulation, and chelation to manage nickel contamination. Rhizofiltration involves the uptake of nickel ions from soil solution through the roots, while phytoaccumulation translocates the absorbed nickel to shoots and leaves, where it can be safely stored (Leblebici et al., 2019). Chelation and compartmentalization of nickel within plant tissues mitigate its toxicity, enabling legumes to tolerate high levels of this heavy metal.

Notable examples of Fabaceae species used for nickel remediation include Crotalaria juncea (Sunn Hemp), which combines rapid growth with significant nickel uptake, and Medicago sativa (Alfalfa), a resilient species that accumulates heavy metals while contributing to soil structure. Similarly, *Vicia faba* (Broad Bean) and *Trifolium* spp. (Clovers) have demonstrated moderate nickel tolerance and uptake, making them suitable candidates for contaminated sites. In addition to their phytoremediation capabilities, Fabaceae plants improve soil structure and fertility, promote microbial diversity, and reduce erosion, further enhancing the ecological value of their use (Zhran et al., 2021). However, challenges such as nickel bioavailability in soil, the slow pace of phytoremediation relative to chemical or physical methods, and the need for safe disposal or utilization of nickel-rich biomass must be addressed to ensure optimal implementation. Research on soil amendments such as chelating agents and biochar can increase nickel bioavailability, while genetic engineering may enhance the uptake and tolerance of these plants (Wang et al., 2022). Expanding field trials in diverse environments will also provide insights into the practical scalability of this technique.

Despite these challenges, Fabaceous plants remain an effective and sustainable solution for addressing nickel contamination. Their ability to restore soil health while extracting heavy metals positions them as an environmentally sound alternative to conventional remediation methods. By integrating ongoing research advancements and field applications, legumes can play a pivotal role in managing heavy metal pollution while supporting broader ecological and agricultural objectives.

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Nickel hyperaccumulation in fabaceous species

Nickel hyperaccumulation in Fabaceous species represents a sophisticated botanical adaptation that enables certain leguminous plants to survive and thrive in metal-contaminated environments. These remarkable plants have evolved complex cellular, genetic and physiological mechanisms to tolerate and accumulate extraordinary concentrations of nickel, often exceeding 1,000 mg/kg of dry weight. At the cellular level, these plants deploy advanced defense strategies, including enhanced antioxidant enzyme systems that neutralize reactive oxygen species, robust membrane protection mechanisms, and specialized metal sequestration techniques. The process involves intricate molecular processes such as phytochelatin production, vacuolar compartmentalization of nickel ions, and activation of metallothionein proteins that effectively bind and neutralize potentially toxic metal concentrations (Yu et al., 2024). Genetically, these Fabaceous hyperaccumulators exhibit unique adaptations characterized by metal-responsive gene upregulation, specialized nickel transport proteins, and dynamic stress response mechanisms (Maier & Benoit, 2019). Species like *Alyssum*, *Thlaspi caerulescens* and specific *Astragalus* varieties demonstrate exceptional nickel tolerance, showcasing nature's remarkable evolutionary strategies. These plants not only survive in nickel-rich environments but also offer significant ecological and technological potential. Their capabilities extend beyond survival, presenting promising applications in phytoremediation, environmental restoration, and biotechnological innovations. Researchers are increasingly focusing on molecular mapping of nickel tolerance genes, exploring genetic engineering approaches, and developing strategies to optimize hyperaccumulation mechanisms.

Advantages and limitations of using fabaceous plants for nickel remediation

Fabaceous plants offer a promising approach to nickel remediation, presenting a range of significant advantages alongside notable challenges. Their primary strengths lie in their remarkable ability to hyperaccumulate nickel, providing an environmentally friendly, cost-effective, and non-invasive method of soil decontamination. These plants demonstrate exceptional metal tolerance, extensive root systems, and rapid biomass production, enabling efficient extraction of nickel from contaminated soils. The biological approach minimizes ecological disruption, promotes soil restoration, and offers potential for biomass conversion, creating additional economic value through metal recovery and sustainable land management.

However, the technique is not without substantial limitations. Species-specific variations in nickel tolerance, complex environmental dependencies, and genetic constraints pose significant challenges to widespread implementation. The efficiency of remediation can be dramatically influenced by soil pH, nutrient availability, temperature, and other environmental factors. Economic feasibility remains a critical concern, as large-scale applications require extensive research, specialized cultivation protocols, and potentially high initial investment. Moreover, the accumulated nickel must be carefully managed, necessitating sophisticated processing and potential disposal strategies.

Despite these challenges, the potential of Fabaceous plants in nickel remediation remains compelling. Ongoing research in genetic engineering, molecular mapping, and optimization of hyperaccumulation mechanisms continues to expand the technological potential of these remarkable plants. Their ability to transform contaminated landscapes represents a promising intersection of ecological restoration, sustainable technology, and environmental management.

Conclusion

Fabaceous plants have emerged as critical models for understanding heavy metal tolerance, showcasing complex defense mechanisms that include advanced antioxidant systems, molecular adaptations, and specialized metal sequestration strategies. These plants do more than merely survive nickel stress; they transform potential ecological challenges into opportunities for environmental restoration and sustainable technological development. The intricate interaction between nickel and Fabaceous plants represents a profound narrative of botanical resilience and adaptive potential. These remarkable leguminous plants have demonstrated extraordinary capabilities to not merely survive but actively transform nickel-contaminated environments through sophisticated cellular and genetic mechanisms. Technological and ecological convergence is emerging as a critical theme, with interdisciplinary approaches that combine biotechnology, ecology and environmental science. The study of Fabaceous plants' nickel tolerance provides insights not just into plant adaptation, but into broader principles of biological resilience and environmental restoration. As global environmental challenges intensify, these plants represent a beacon of hope, demonstrating nature's remarkable capacity to develop innovative solutions to complex ecological problems.

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Future Perspectives

The future research landscape challenges scientists to move beyond mere observation, towards developing comprehensive strategies for environmental management. This involves creating engineered plant varieties, exploring biomass conversion techniques, and developing integrated approaches to ecosystem restoration. The ultimate goal transcends scientific curiosity, aiming to create sustainable, adaptable solutions that can address global environmental degradation.

Philosophically and practically, these plants offer a powerful narrative of transformation and resilience. They remind us that life possesses an extraordinary capacity to adapt, survive, and potentially thrive under challenging conditions. Each scientific discovery opens new pathways of understanding, promising innovative approaches to environmental challenges and offering hope for more sustainable interactions between human activities and natural ecosystems.

Conflict of interest

None

References

Abbas, F., Ashraf, M. A., Rasheed, R., & Iqbal, M. (2025). Citrulline Subsided Nickel Toxicity in Rice (Oryza sativa L.) by Modulating Photosynthesis, Metabolic Dysregulations, Metal Sequestration and Nutrient Uptake. *Russian Journal of Plant Physiology*, *72*(5), 154. https://doi.org/10.1134/S1021443725602113

Adejumo, S. A., Oniosun, B., Akpoilih, O. A., Adeseko, A., & Arowo, D. O. (2021). Anatomical changes, osmolytes accumulation and distribution in the native plants growing on Pb-contaminated sites. *Environmental Geochemistry and Health*, *43*, 1537-1549. https://doi.org/10.1007/s10653-020-00649-5

Antonkiewicz, J., Jasiewicz, C., Koncewicz-Baran, M., & Sendor, R. (2016). Nickel bioaccumulation by the chosen plant species. *Acta Physiologiae Plantarum*, *38*, 1-11. https://doi.org/10.1007/s11738-016-2062-5

Awa, S. H., & Hadibarata, T. (2020). Removal of heavy metals in contaminated soil by phytoremediation mechanism: a review. *Water, Air, & Soil Pollution*, *231*(2), 47.

Begum, W., Rai, S., Banerjee, S., Bhattacharjee, S., Mondal, M. H., Bhattarai, A., & Saha, B. (2022). A comprehensive review on the sources, essentiality and toxicological profile of nickel. *RSC Advances*, *12*(15), 9139-9153. https://doi.org/10.1039/D2RA00378C

Chen, X., Ren, Y., Li, C., Shang, Y., Ji, R., Yao, D., & He, Y. (2024). Study on factors influencing the migration of heavy metals from soil to vegetables in a heavy industry city. *Sustainability*, *16*(24), 11084. https://doi.org/10.3390/su162411084

Das, K. K., Reddy, R. C., Bagoji, I. B., Das, S., Bagali, S., Mullur, L., ... & Biradar, M. S. (2019). Primary concept of nickel toxicity–an overview. *Journal of basic and clinical physiology and pharmacology*, *30*(2), 141-152. https://doi.org/10.1515/jbcpp-2017-0171

Deep, S. K., Patra, B., Mohanta, A. K., Ekka, R. K., Sethi, B. K., Behera, P. K., & Pradhan, S. N. (2023). Role of critical contaminants in groundwater of Kalahandi district of Odisha and their health risk assessment. *Annals of Forest Research*, *66*(1).

Deng, T. H. B., van der Ent, A., Tang, Y. T., Sterckeman, T., Echevarria, G., Morel, J. L., & Qiu, R. L. (2018). Nickel hyperaccumulation mechanisms: a review on the current state of knowledge. *Plant and Soil*, *423*, 1-11. https://doi.org/10.1007/s11104-017-3539-8

Deswal, M., & Laura, J. S. (2018). Effect of heavy metals cadmium, nickel and lead on the seed germination and early seedling growth of Pisum sativum. *Res. J. Life Sci. Bioinform. Pharm. Chem. Sci.*, *4*, 368-383. https://doi.org/10.26479/2018.0402.29

Dijoux, J., Gigante, S., Lecellier, G., Guentas, L., & Burtet-Sarramegna, V. (2025). Plant nickel-exclusion versus hyperaccumulation: a microbial perspective. *Microbiome*, *13*(1), 110. https://doi.org/10.1186/s40168-025-02098-7

El-Naggar, A., Ahmed, N., Mosa, A., Niazi, N. K., Yousaf, B., Sharma, A., ... & Chang, S. X. (2021). Nickel in soil and water: Sources, biogeochemistry, and remediation using biochar. *Journal of hazardous materials*, *419*, 126421. https://doi.org/10.1016/j.jhazmat.2021.126421

Farago, M. E., & Cole, M. M. (2024). Nickel and plants. In *Metal ions in biological systems* (pp. 47-90). CRC Press.

Feng, R., Wang, L., Yang, J., Zhao, P., Zhu, Y., Li, Y., ... & Zheng, S. (2021). Underlying mechanisms responsible for restriction of uptake and translocation of heavy metals (metalloids) by

selenium via root application in plants. *Journal of Hazardous Materials*, *402*, 123570. https://doi.org/10.1016/j.jhazmat.2020.123570

Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., ... & Yan, C. (2022). Pollution and health: a progress update. *The Lancet Planetary Health*, *6*(6), e535-e547. https://doi.org/10.1016/S2542-5196(22)00090-0

Ge, J., Wang, H., Lin, J., Tian, S., Zhao, J., Lin, X., & Lu, L. (2020). Nickel tolerance, translocation and accumulation in a Cd/Zn co-hyperaccumulator plant Sedum alfredii. *Journal of Hazardous Materials*, *398*, 123074. https://doi.org/10.3389/fpls.2020.00610

Ge, J., Wang, H., Lin, J., Tian, S., Zhao, J., Lin, X., & Lu, L. (2020). Nickel tolerance, translocation and accumulation in a Cd/Zn co-hyperaccumulator plant *Sedum alfredii*. *Journal of Hazardous Materials*, *398*, 123074. https://doi.org/10.1016/j.jhazmat.2020.123074

Hassan, M. U., Chattha, M. U., Khan, I., Chattha, M. B., Aamer, M., Nawaz, M., ... & Khan, T. A. (2019). Nickel toxicity in plants: reasons, toxic effects, tolerance mechanisms, and remediation possibilities—a review. *Environmental Science and Pollution Research*, *26*, 12673-12688. https://doi.org/10.1007/s11356-019-04892-x

Jach, M. E., Sajnaga, E., & Ziaja, M. (2022). Utilization of legume-nodule bacterial symbiosis in phytoremediation of heavy metal-contaminated soils. *Biology*, *11*(5), 676. https://doi.org/10.3390/biology11050676

Jali, P., Acharya, S., Mahalik, G., Pradhan, C., & Das, A. B. (2019). Low dose cadmium (II) induced antifungal activity against blast disease in rice. *Physiological and Molecular Plant Pathology*, *108*, 101422. https://doi.org/10.1016/j.pmpp.2019.101422

Khalid, S., Shahid, M., Niazi, N. K., Murtaza, B., Bibi, I., & Dumat, C. (2017). A comparison of technologies for remediation of heavy metal contaminated soils. *Journal of Geochemical Exploration*, *182*, 247-268. https://doi.org/10.1016/j.gexplo.2016.11.021

Khan, S., Al-Qurainy, F., Al-hashimi, A., Nadeem, M., Tarroum, M., Gaafar, A. R. Z., ... & Karuppiah, P. (2024). Molecular phylogeny, phenolics content, and antimicrobial activity of some potential medicinal plant species of the Fabaceae family collected from different geographical regions of Saudi Arabia. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology*, *158*(6), 1482-1492. https://doi.org/10.1080/11263504.2024.2424247

Khudhur, S. A., & Albarzinji, I. M. (2023). Effects of Lead and Nickel on Seed Germination and Vegetative Growth on some Fabaceae Species. *Zanco Journal of Pure and Applied Sciences*, *35*(SpD). http://dx.doi.org/10.21271/zjpas

Kováčik, J., & Vydra, M. (2024). The impact of nickel on plant growth and oxidative balance. *Physiologia plantarum*, *176*(6), e14595.

Kumar, A., & Verma, J. S. (2018). Effects of nickel chloride on germination and seedling growth of different wheat (*Triticum aestivum* L. em Thell.) cultivars. *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 2227-2234.

Kumar, V., Rout, C., Singh, J., Malik, S., Umar, A., Ibrahim, A. A., & Baskoutas, S. (2025). Enhanced heavy metal removal from contaminated soils using chelation and adsorption synergy. *International Journal of Environmental Science and Technology*, *22*(15), 15409-15424. ttps://doi.org/10.1007/s13762-025-06592-1

Laoye, B., Olagbemide, P., Ogunnusi, T., & Akpor, O. (2025). Heavy metal contamination: Sources, health impacts, and sustainable mitigation strategies with insights from Nigerian case studies. *F1000Research*, *14*, 134. https://doi.org/10.5256/f1000research.178309.r372442

Leblebici, Z., Dalmiş, E., & Andeden, E. E. (2019). Determination of the potential of Pistia stratiotes L. in removing nickel from the environment by utilizing its rhizofiltration capacity. *Brazilian Archives of Biology and Technology*, *62*, e19180487. https://doi.org/10.1590/1678-4324-2019180487

Li, L., Zhu, Z., Liao, Y., Yang, C., Fan, N., Zhang, J., ... & Huang, C. F. (2022). NRAMP6 and NRAMP1 cooperatively regulate root growth and manganese translocation under manganese deficiency in Arabidopsis. *The Plant Journal*, *110*(6), 1564-1577. https://doi.org/10.1111/tpj.15754

Liu, G., Simonne, E. H., & Li, Y. (2024). Nickel nutrition in plants.

Liu, H., Cui, Y., Zhou, J., Penttinen, P., Liu, J., Zeng, L., ... & Yu, X. (2022). Nickel mine soil is a potential source for soybean plant growth promoting and heavy metal tolerant rhizobia. *PeerJ*, *10*, e13215.

Ma, Z., Chen, M., Lu, J., Liu, S., & Ma, Y. (2025). Exploration of urease-aided calcium carbonate mineralization by enzyme analyses of *Neobacillus mesonae* strain NS-6. *Microbiology Spectrum*, *13*(1), e01891-24.

Maier, R. J., & Benoit, S. L. (2019). Role of nickel in microbial pathogenesis. *Inorganics*, *7*(7), 80. https://doi.org/10.3390/inorganics7070080

Manirakiza, N., Théophile, N., Christophe, N., Kishota Papy, M. K. P., Patrice, B., & C Gisèle, J. (2024). Phytoremediation Evaluation of Nickel-Contaminated Soil Using Panicum Maximum under Humid Tropical Climate. *International Journal of BioLife Sciences (IJBLS)*, *3*(3), 285-295.

Manjunatha, L., Vadlapudi, K., Torankumar, S., Poornima, D. V., Rajashekar, J., & Hari, G. (2019). Influence of nickel treatment on antioxidant responses and secondary metabolite production in *Eryngium foetidium* Linn. *Indian Journal of Pure and Applied Biosciences*, *7*(5), 314-326. http://dx.doi.org/10.18782/2320-7051.7851

Mendes, N. A. C., Cunha, M. L. O., Bosse, M. A., Silva, V. M., Moro, A. L., Agathokleous, E., ... & Dos Reis, A. R. (2023). Physiological and biochemical role of nickel in nodulation and biological nitrogen fixation in *Vigna unguiculata* L. Walp. *Plant Physiology and Biochemistry*, *201*, 107869.

Mendes, N. A. C., Cunha, M. L. O., Bosse, M. A., Silva, V. M., Moro, A. L., Agathokleous, E., ... & Dos Reis, A. R. (2023). Physiological and biochemical role of nickel in nodulation and biological nitrogen fixation in *Vigna unguiculata* L.

Mishra, S., Bhuyan, N. K., Mohapatra, R. K., & Das, H. K. (2018). Seasonal assessment of groundwater quality in terms of heavy metal contamination in Sukinda mining region of Jajpur District, Odisha. *International Journal of Development Research*, *8*(04), 19815-19820.

Moameri, M., Jafari, M., Tavili, A., Motasharezadeh, B., & Zare Chahouki, M. A. (2017). Rangeland plants potential for phytoremediation of contaminated soils with lead, zinc, cadmium and nickel (Case study: Rangelands around national lead & zinc factory, Zanjan, Iran). *Journal of Rangeland Science*, *7*(2), 160-171.

Mussali-Galante, P., Gómez-Arroyo, S., Rodríguez-Solís, A., Valencia-Cuevas, L., Flores-Márquez, A. R., Castrejón-Godínez, M. L., ... & Tovar-Sánchez, E. (2024). Multi-biomarker approach reveals the effects of heavy metal bioaccumulation in the foundation species *Prosopis laevigata* (Fabaceae). *Environmental Science and Pollution Research*, *31*(34), 47116-47131. https://doi.org/10.1007/s11356-024-34239-0

Mussali-Galante, P., Santoyo-Martínez, M., Castrejón-Godínez, M. L., Breton-Deval, L., Rodríguez-Solis, A., Valencia-Cuevas, L., & Tovar-Sánchez, E. (2023). The bioaccumulation potential of heavy metals by *Gliricidia sepium* (Fabaceae) in mine tailings. *Environmental Science and Pollution Research*, *30*(13), 38982-38999. https://doi.org/10.1007/s11356-022-24904-7

Mustafa, A., Zulfiqar, U., Mumtaz, M. Z., Radziemska, M., Haider, F. U., Holatko, J., ... & Brtnicky, M. (2023). Nickel (Ni) phytotoxicity and detoxification mechanisms: A review. *Chemosphere*, *328*, 138574. https://doi.org/10.1016/j.chemosphere.2023.138574

Nabi, A., Naeem, M., Aftab, T., & Khan, M. M. A. (2020). Alterations in photosynthetic pigments, antioxidant machinery, essential oil constituents and growth of menthol mint (*Mentha arvensis* L.) upon nickel exposure. *Brazilian Journal of Botany*, *43*, 721-731. https://doi.org/10.1007/s40415-020-00649-w

Nishida, S., Tanikawa, R., Ishida, S., Yoshida, J., Mizuno, T., Nakanishi, H., & Furuta, N. (2020). Elevated expression of vacuolar nickel transporter gene IREG2 is associated with reduced root-to-shoot nickel translocation in *Noccaea japonica*. *Frontiers in Plant Science*, *11*, 610. https://doi.org/10.3389/fpls.2020.00610

Nkrumah, P. N., Echevarria, G., Erskine, P. D., Chaney, R. L., Sumail, S., & van Der Ent, A. (2019). Effect of nickel concentration and soil pH on metal accumulation and growth in tropical agromining 'metal crops'. *Plant and Soil*, *443*, 27-39. https://doi.org/10.1007/s11104-019-04200-z

Panda, D. K., Jyotirmayee, B., & Mahalik, G. (2022). Black rice: A review from its history to chemical makeup to health advantages, nutritional properties and dietary uses. *Plant Science Today, 9*(sp3), 01-15. https://doi.org/10.14719/pst.1817

Pandey, S. N. (2020). Fabaceous Plants Under Abiotic Stresses and Biochemical Functions of Micronutrients. *The Plant Family Fabaceae: Biology and Physiological Responses to Environmental Stresses*, 417-433.

Pandey, S. N. (2020). Fabaceous Plants Under Abiotic Stresses and Biochemical Functions of Micronutrients. *The Plant Family Fabaceae:*

Biology and Physiological Responses to Environmental Stresses, 417-433. https://doi.org/10.1007/978-981-15-4752-2_16

Pasricha, S., Mathur, V., Garg, A., Lenka, S., Verma, K., & Agarwal, S. (2021). Molecular mechanisms underlying heavy metal uptake, translocation and tolerance in hyperaccumulators-an analysis: Heavy metal tolerance in hyperaccumulators. *Environmental Challenges*, *4*, 100197. https://doi.org/10.1016/j.envc.2021.100197

Pierre, J. F. (2024). Legumes: cornerstones of global food security and sustainable agriculture. In *Legume Crops for Food Security-Cultivation and Benefits*. IntechOpen.

Praharaj, S., & Maitra, S. (2020). Importance of legumes in agricultural production system: An overview. *Agro Econ*, *7*(2), 69-71.

Qin, C., Shen, J., & Ahanger, M. A. (2022). Supplementation of nitric oxide and spermidine alleviates the nickel stress-induced damage to growth, chlorophyll metabolism, and photosynthesis by upregulating ascorbate–glutathione and glyoxalase cycle functioning in tomato. *Frontiers in Plant Science*, *13*, 1039480. https://doi.org/10.3389/fpls.2022.1039480

Raza, A., Zahra, N., Hafeez, M. B., Ahmad, M., Iqbal, S., Shaukat, K., & Ahmad, G. (2020). Nitrogen fixation of legumes: Biology and Physiology. *The plant family Fabaceae: biology and physiological responses to environmental stresses*, 43-74. https://doi.org/10.1007/978-981-15-4752-2_3

Reinprecht, Y., Schram, L., Marsolais, F., Smith, T. H., Hill, B., & Pauls, K. P. (2020). Effects of nitrogen application on nitrogen fixation in common bean production. *Frontiers in plant Science*, *11*, 1172. https://doi.org/10.3389/fpls.2020.01172

Riyazuddin, R., Nisha, N., Ejaz, B., Khan, M. I. R., Kumar, M., Ramteke, P. W., & Gupta, R. (2021). A comprehensive review on the heavy metal toxicity and sequestration in plants. *Biomolecules*, *12*(1), 43. https://doi.org/10.3390/biom12010043

Sahoo, H. B., Gandre, D. K., Das, P. K., Karim, M. A., & Bhuyan, G. C. (2018). Geochemical mapping of heavy metals around Sukinda–Bhuban area in Jajpur and Dhenkanal districts of Odisha, India. *Environmental Earth Sciences*, *77*, 1-17. https://doi.org/10.1007/s12665-017-7208-2

Samreen, S., Khan, A. A., Khan, M. R., Ansari, S. A., & Khan, A. (2021). Assessment of phytoremediation potential of seven weed plants growing in chromium-and nickel-contaminated soil. *Water, Air, & Soil Pollution*, *232*, 1-18.

Santoyo-Martínez, M., Mussali-Galante, P., Hernández-Plata, I., Valencia-Cuevas, L., Rodríguez, A., Castrejón-Godínez, M. L., & Tovar-Sánchez, E. (2024). Phytoremediation potential of Crotalaria pumila (Fabaceae) in soils polluted with heavy metals: Evidence from field and controlled experiments. *Plants*, *13*(14), 1947.

Selvam, R., Kalaiyarasi, G., & Saritha, B. (2024). Heavy metal contamination in soils: risks and remediation. *Soil Fertility and Plant Nutrition*, *141*.

Shafiq, A., Munawar, M. E., Nadeem, M., Khan, A., Abbasi, G. H., Haq, M. A. U., ... & Awais, M. (2024). Health risk assessment of bread wheat grown under cadmium and nickel stress and impact of silicic acid application on its growth, physiology, and metal uptake. *Environmental Science and Pollution Research*, *31*(43), 55535-55548.

Shahzad, A., Siddique, A., Ferdous, S., Amin, M. A., Qin, M., Aslam, U., ... & Shakoor, A. (2023). Heavy metals mitigation and growth-promoting effect of endophytic *Agrococcus terreus* (MW 979614) in maize plants under zinc and nickel contaminated soil. *Frontiers in Microbiology*, *14*, 1255921. https://doi.org/10.3389/fmicb.2023.1255921

Shahzad, B., Tanveer, M., Rehman, A., Cheema, S. A., Fahad, S., Rehman, S., & Sharma, A. (2018). Nickel; whether toxic or essential for plants and environment-A review. *Plant physiology and Biochemistry*, *132*, 641-651. https://doi.org/10.1016/j.plaphy.2018.10.014

Shi, J., Qian, W., Jin, Z., Zhou, Z., Wang, X., & Yang, X. (2023). Evaluation of soil heavy metals pollution and the phytoremediation potential of copper-nickel mine tailings ponds. *Plos one*, *18*(3), e0277159.

Siddiqui, S. (2025). Global patterns and drivers of species and genera richness of Fabaceae. *Frontiers in Plant Science*, *16*, 1581814. http://dx.doi.org/10.3389/fpls.2025.1581814

Singh, P., & Yadav, D. (2021). Link between air pollution and global climate change. In *Global climate change* (pp. 79-108). Elsevier. https://doi.org/10.1016/B978-0-12-822928-6.00009-5

Sujkowska-Rybkowska, M., Rusaczonek, A., Kasowska, D., Gediga, K., Banasiewicz, J., Stępkowski, T., & Bernacki, M. J. (2022). Potential of Rhizobia Nodulating *Anthyllis vulneraria* L. from Ultramafic Soil as Plant Growth Promoting Bacteria Alleviating Nickel Stress in *Arabidopsis thaliana* L. *International Journal of Molecular Sciences*, *23*(19), 11538. https://doi.org/10.1080/15226514.2018.1524828

Tak, N., & Gehlot, H. S. (2019). Diversity of nitrogen-fixing symbiotic rhizobia with special reference to Indian Thar Desert. *Microbial Diversity in Ecosystem Sustainability and Biotechnological Applications: Volume 2. Soil & Agroecosystems*, 31-55. https://doi.org/10.1007/978-981-13-8487-5_2

Thakur, S., & Sharma, S. S. (2016). Characterization of seed germination, seedling growth, and associated metabolic responses of *Brassica juncea* L. cultivars to elevated nickel concentrations. *Protoplasma*, *253*, 571-580. https://doi.org/10.1007/s00709-015-0835-0

Vardhan, K. H., Kumar, P. S., & Panda, R. C. (2019). A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives. *Journal of Molecular Liquids*, *290*, 111197. https://doi.org/10.1016/j.molliq.2019.111197

Vasconcelos, M. W., Grusak, M. A., Pinto, E., Gomes, A., Ferreira, H., Balázs, B., ... & Iannetta, P. (2020). The biology of legumes and their agronomic, economic, and social impact. *The plant family Fabaceae: biology and physiological responses to environmental stresses*, 3-25. https://doi.org/10.1007/978-981-15-4752-2_1

Vyas, M. K. (2022). The toxic effects of nickel and cadmium on germination, seedling growth and biochemical contents of *Rauwolfia serpentina* Benth. ex Kruz. *Journal of Stress Physiology & Biochemistry*, *18*(1), 76-87.

Wang, J., Zhang, Y., Yu, L., Cui, K., Fu, T., & Mao, H. (2022). Effective separation and recovery of valuable metals from waste Ni-based batteries: A comprehensive review. *Chemical Engineering Journal*, *439*, 135767. https://doi.org/10.1016/j.cej.2022.135767

Williams, E. T. (2019). Environmental pollution by heavy metal: an overview. *International Journal of Environmental Chemistry*, *12*(2), 72-82. https://doi.org/10.11648/j.ijec.20190302.14

Yu, H., Li, W., Liu, X., Song, Q., Li, J., & Xu, J. (2024). Physiological and molecular bases of the nickel toxicity responses in tomato. *Stress Biology*, *4*(1), 25.

Zhran, M., Moursy, A., Lynn, T. M., & Fahmy, A. (2021). Effect of urea fertilization on growth of broad bean (*Vicia faba* L.) under various nickel (Ni) levels with or without acetic acid addition, using 15 N-labeled fertilizer. *Environmental Geochemistry and Health*, *43*, 2423-2431. https://doi.org/10.1007/s10653-020-00707-y

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